INDUSTRIAL HYGIENE SECTION

This Industrial Hygiene Section is published to promote sound thought upon and concerning industrial hygiene. To that end it will contain articles, discussions, news items, reports, digests, and other presentations, together with editorial comments. The editorial policy is to encourage frank discussion. On this basis contributions are invited.

Industrial Medicine
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The Science, the Law and the Economics of Industrial Health

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Apparatus and Methods

—For Testing the Toxicity of Vapors—

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A NUMBER of devices have been assembled for maintaining a controlled concentration of a vapor in air for the purpose of testing the toxicity of that vapor. We note particularly such devices as have been constructed at the Bureau of Mines in Pittsburgh, the United States Public Health Service in Washington, the Kettering Laboratory in Cincinnati, the Harvard School of Public Health, and others. There are certain basic essentials to any such apparatus which we wish to discuss briefly. There is nothing particularly unique about our own set-up. It is, however, a combination which has evolved over a number of years and has been found very satisfactory. A keen interest shown by several individuals has led us to believe that the presentation of the essentials of this apparatus and its use would be of interest to workers in the field of toxicology and industrial hygiene engineering.

Any apparatus of this type is made up of certain essential elements. We have classified them arbitrarily as follows:

1. The supply of air.
2. The supply of the material to be tested.
3. Metering.
4. Mixing.
5. The chamber for exposure.
6. A proper exhaust system.
7. A means of sampling the gases in the chamber.
8. The analytical methods.
9. The quality and control of test animals.

Air Supply

VAPOR toxicity experiments are carried out using either a static charge or a continuous flow of a vapor-air mixture. We are considering the continuous flow. The primary considerations

in the air supply are purity, temperature, humidity, and flow.

In a location where the air is reasonably free from extraneous materials it is satisfactory without purification. In a chemical plant or an industrial district it is necessary to purify the air. This may be done by various methods of washing or filtering. We bring all the air for the animal house and for the room containing the chambers through a system containing first a dust filter, then activated charcoal. The air is then heated and humidified. In this way the control animal is exposed to a normal supply of reasonably pure air, and the test animal receives in addition only the material intended for test. Because small amounts of materials occasionally escape into the room containing the chambers, an activated charcoal filter is used also in the intake to each chamber.

Abnormal temperature and humidity conditions affect strongly the physiological state of the animal and, therefore, affect the response of the animal to the material to be tested. We have attempted here to expose our animals to a uniformly normal healthful supply of air and thereby record a more reproduceable response to the exposure to the test material.

In maintaining the proper flow of air some type of pump is required. The pump may be used to force the air through the apparatus or to pump it through at reduced pressure with the pump at the exit of the chamber. The last method is most desirable and is used by most workers in this field.

There are numerous types of pumps that may be used. Reciprocating piston pumps and diaphragm pumps require valves and furnish an intermittent delivery which would require a reservoir to smooth out the flow. Screw and gear pumps are more usable for liquids. Vane and cycloid pumps are very satisfactory for our purposes. The vane pumps are more readily available in small sizes and have been most used for this reason.

Supply of Material to be Tested

WHERE relatively large volumes are required, pumps of the type just mentioned could be used; the type depending upon the state of the material, that is, gas or liquid.

In actual experience, however, the flows used for test materials are usually very low. We have therefore used specially designed metering pumps for this purpose. These pumps will be discussed in considering metering devices. It is assumed, of course, that the test material must be of high purity if any conclusions are to be drawn from the work. In many circumstances the hazard presented is from mixed vapors. In such cases the mixture tested should be of carefully controlled composition if any significance is to be attached to the results.

The nature of the material will determine the method of handling the supply. The higher boiling liquids can be metered as liquids and volatilized in the air stream. Liquids boiling at a low level but well above room temperature can be metered as liquids by maintaining them at a low temperature while metering. Lower boiling liquids can be metered as gases by increasing the temperature. This can be done by storing the liquid in a steel cylinder which is placed in a heated oil bath. The gas is then taken off under pressure and metered at a high temperature to maintain the gaseous state. Gases are metered as gases at ordinary temperatures. The metering of these materials is all done at a constant temperature.

Methods of Metering

THERE are a great many types of metering devices for measuring flow. "Head" meters are a common and useful type. They are based on the common principle of a differential pressure between two points in the flow.

The impact tube such as the pitot tube measures the velocity head at a point in the flow.

A second type of head meter depends upon the differential pressure across a standard constriction in the line of flow. Various shaped nozzles and the venturi are of this type. The rounded and sharp edged orifices are, however, the most common in use. We have used the sharp edged orifice for larger flows, while for small flows we have used a glass capillary orifice of arbitrary design. This requires calibration against a standard instrument such as a wet test meter or a gasometer. The sharp edged orifice meter is designed to certain determined standards, and the calibration can be calculated. Any change in temperature or downstream pressure will affect the flow reading, and some correction must be made for such changes.

Another type of meter which is satisfactory for both gas and liquid flows is the "Rotameter." This meter depends upon the support of a small "rotor" in a tapered tube by the upward flow of the fluid. The sides of the tube are calibrated and the flow can be read from the height of the "rotor."

There are several gas volume meters which are useful here in calibrating flow meters and in sampling. The wet test meter and the gasometer are examples of this type.

In metering air for a chamber the orifice meters are very satisfactory. However, in metering materials to be tested the flows may be as low as one or two cubic centimeters per minute. Such flows require a special metering apparatus. At the Bureau of Mines a pump for metering liquid flows has been designed consisting essentially of a loose plunger displacement pump run by a constant speed motor. We have adopted that principle in our pumps. As these pumps are not continuous but are limited to the volume of a single filling, we have built them in pairs so that we could switch from one pump to the other without interrupting the flow. The pumps can then be filled alternately.

A gas pump is designed as shown in Fig. 1. A loose plunger is lowered into a liquid reservoir by a constant speed electric clock motor. The liquid is displaced flowing into a side tube and thence to the base of a gas reservoir. This liquid displaces the gas which escapes through a mercury trap of very low back pressure. The trap is necessary in order to prevent back diffusion at low flows. This whole apparatus is inclosed in a constant temperature air bath. The rate of flow may

be adjusted by changing the size of the plunger, by changing the size of the lowering drum, or by changing the speed of the clock motor. The metering fluid will vary somewhat with the gas to be metered. In metering organic vapors a near saturated brine of magnesium sulfate is very satisfactory. The apparatus is so arranged that in filling the gas chamber the pressure of the gas is used to force the metering liquid through a by-pass back into the pump cylinder.

In metering liquids the first part of the described pump mechanism can be used by direct displacement of the liquid to be metered in place of the brine. This liquid flow is then volatilized in the air flow to the chamber. Warming the area of pipe where volatilization takes place will aid in uniform mixing. It is sometimes desirable to cut down vaporization from the top of the pump in low boiling liquids. This can be readily done by capping the

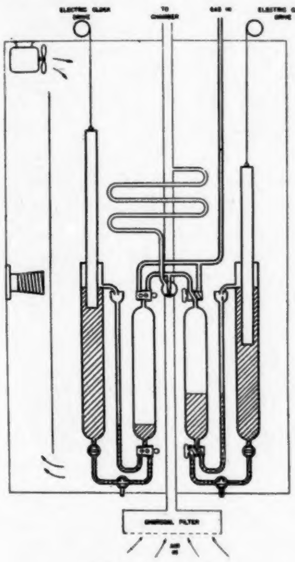

Fig. 1. Gas pump

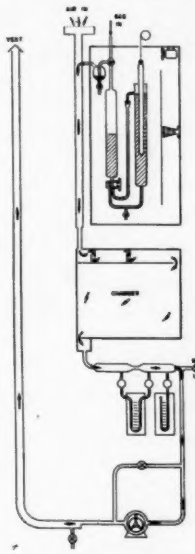

Fig. 2. Gassing assembly

pump with a thin rubber sheet such as dental or surgical dam. The plunger passes through this without serious resistance.

There are a number of small tricks to designing and handling these pumps which one gets through experience. They are, however, positive in action and very accurate in performance.

There are two other types of pumps used for very small liquid flows. One uses a standard glass syringe driven by a screw which is in turn driven by a constant speed motor. This is a non-continuous type pump and can be used somewhat as the type just described. The second is a continuous type, consisting of a rubber tube which is "milked" by a rotor run at constant speed.

Mixing

AFTER metering the air and vapor, the next step is proper mixing. This is a relatively simple matter but also a very essential one. A turbulent flow in sufficient length of pipe will accomplish the required mixing. The same can be accomplished by baffles in a mixing chamber prior to entrance into the testing chamber. In larger chambers it is desirable to have a mixing fan. If the intake enters the line of the fan, a proper mixing results. The fan should not create a strong directioned wind, however, in the animal chamber. A most satisfactory device is a large slow-speed fan.

The Chamber

THERE are any number of designs for a chamber. The essential factors are: an air tight space of known volume; a surface readily cleaned, impervious and resistant to the vapors to be tested; ready visability for viewing the activity of test animals; and a design and cost which is practical.

We have used two types of chambers: a small box with glass walls set in a monel frame, and a larger chamber which is a wood box lined with a thin sheet of corrosion resistant metal. The volumes are respectively 5.5 cu. ft. and 6.6 cu. ft.

Exhaust System

EXHAUSTING is usually a matter of venting the exhaust from a chamber to the roof where it will be carried away from the building and rapidly diluted. If you are working with high concentrations of a particularly noxious material, it may be necessary to use a scrubbing tower or absorber. We have not as yet found this necessary.

Sampling

SAMPLING is a very important part of the operation of a chamber. Samples are most readily taken from the exhaust system. It is often desirable, however, to sample from the center of the chamber, and sampling tubes should be provided. The collection of the sample varies with the vapor being tested and the analytical method to be applied. The air sample is drawn from the chamber through a reaction or absorption cell and then through a wet test meter or gasometer. When a sufficient, accurately measured volume is drawn through to furnish a sample large enough for analysis the cell can be removed.

The mechanism for removing the vapors may be of several types:

1. A combustion tube and absorption tower. The combustion is usually carried out in an electrically heated tube containing a catalyst. The vapors are then absorbed in a packed bubbling tower.
2. A direct chemical reaction in a bubbling tower or the like.
3. A cold trap containing a solvent maintained at a very low temperature.
4. An absorber using activated charcoal or silica gel.
5. A sample flask for removal of a measured volume of vapor-air mixture for subsequent analysis. This may be used by simple displacement of an inert liquid or by evacuating the flask.

Analysis

EVERY new material studied is an analytical problem in itself. There are certain generalities that can be discussed in this connection.

Analysis can be carried out by direct physical analysis or by chemical methods.

The direct physical methods are rapid and can be run on samples direct from the chamber. This has great advantages in making a rapid check. The results, however, are always questionable and should be taken with a grain of salt. We refer here particularly to the interferometer and the thermal conductivity cell.

The spectrographic methods could be called physical but are entirely different from the two just mentioned in being more specific. Spectrographic measurement can be made on samples cold-trapped in a solvent or absorbed by other means in a pure chemical medium appropriate to the method.

The majority of methods consists of appropriate chemical analysis on samples collected by various means, the nature of the analytical procedure being a function of the material to be analyzed.

Quality and Control of Test Animals

WHILE the animal is not ordinarily considered to be part of the apparatus, he is certainly a most essential part of the procedure. We have discovered through sad experience that it is difficult, if not impossible, to obtain proper experimental animals on the open market. It is most essential to have a colony of animals free from all disease or abnormality. When the pathological state of control animals is worse than will be produced by exposure to the test material, the experiment is of course useless.

An Assembled Apparatus

OUR particular set-up is an assembly of the essential elements as indicated (see Fig. 2). The small glass chamber assembly is a simple apparatus. The air starts at normal temperature and humidity in the room. It enters through the activated charcoal filter and down a monel pipe. In this pipe the vapor to be studied is introduced after being metered by a displacement pump of the type described. The air-vapor mixture passes into the top of the chamber which is a separate mixing chamber with four baffles. The well mixed gases then enter the chamber through a long narrow slit the length of the front of the chamber.

Fig. 3. Group of small gassing chambers

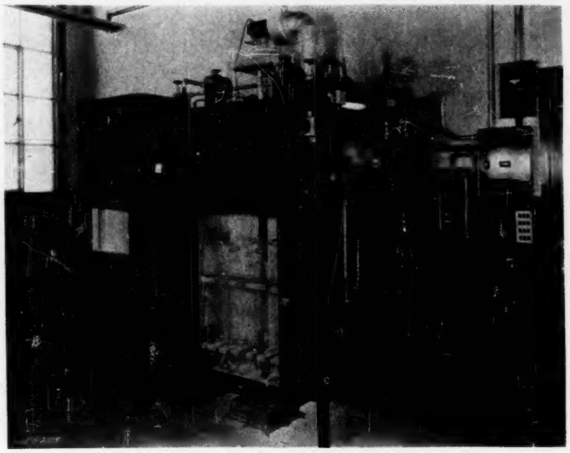

Fig. 4. Large gassing chamber

Passing around the animals the gases escape through a long slit in the lower back edge of the chamber. An orifice flow meter is introduced into the line at this point which measures the total flow through the chamber. After metering a sample may be taken from the line for analysis. The gases then pass to a vane pump and to the exhaust stack. A photograph of a group of these chambers is shown in Fig. 3.

The larger chamber we have used for larger animals and more particularly for chronic experiments. It is constructed on similar principles except that it is metal-lined, and the gases are mixed within the chamber by a large slow-revolving fan. A photograph of this apparatus is shown in Fig. 4.

With the type of apparatus described we have maintained over long periods of time a concentration of vapor in air equivalent to 30 parts per million by volume with very good accuracy. Most of our chambers have been running 24 hours a day continuously, except for week ends, for several years and with very little trouble.

In starting up each change of animals it is necessary to introduce a measured "slug" of toxic vapor to bring the concentration nearly up to the desired level at once. From then on the desired concentration is maintained in the air stream by the apparatus as indicated above.

Procedures for Establishing the Toxicity of Vapors

THERE are two major objectives in vapor toxicity studies. First, the acute vapor toxicity; and, second, the chronic vapor toxicity. No definitions have been established for these terms nor have any standards been accepted for procedures in determining toxic levels. We have therefore adopted whatever procedures proved most applicable to our purposes and established them as our standards.

Acute Vapor Toxicity

WE HAVE arbitrarily defined this procedure as concerned with single exposures of intervals from one-half to 24 hours. A series of time intervals and a series of concentration levels are used on the basis of experience or preliminary

test. A group of animals is exposed to each time interval concentration level point. After the animals have been observed for a month or six weeks after exposure a mortality table is established. The data are then plotted on log-log scale as used by SAYERS and YANT.[1] We have made one exception to this method. We plot two curves: one represents the lowest concentration level—shortest time interval where all animals die; the other representing the highest concentration level—longest time interval at which all animals survive. This chart gives a clear picture of the acute toxicity of the vapor studied.

Chronic Vapor Toxicity

SOME reasonable period of exposure had to be chosen in extended chronic studies. A period of eight hours exposure and an interval of 16 hours between exposures has been arbitrarily chosen. SMYTH and SMYTH[2] used the same interval. It has some reasonable basis in our standard work day. These eight hours per day exposures are continued with week end intervals of rest for a period up to six months. Occasionally a longer total than six months is used but this is our standard. There is no doubt that a different period of exposure or a different interval of rest between exposures would change the results profoundly. Studies of the effect of interval variation would be most illuminating when time permits. Several different species of animal should be tested in order to avoid the individual vagaries of any one species. We have, however, used the rat as preferable for a standard animal.

At intervals during the six months, exposed animals are removed for complete histological study and at the conclusion of any series of exposures all the remaining animals are so examined. Other important studies made during chronic exposures are blood examinations, tissue analysis, urine analysis, and function tests where such are indicated.

Such complete toxicological studies on the chronic vapor toxicity of even our common chemicals are few and far between. They are, however, the basis upon which the industrial hygienist and safety engineer must base his work. Nearly any material may be handled in industry without serious hazard if its properties including its physiological effect are clearly understood and intelligently used.

The procedures and apparatus just discussed are for the purpose of furnishing in so far as it is possible the toxicological data by which an intelligent engineer can design or control an industrial plant for the manufacture or use of essential chemicals with the minimum of hazard.

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Air Sampling of Asbestos Dust

—*Comparison of Impinger and Electrostatic Precipitator Methods**—

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DURING the past 10 years the Industrial Health Section of the Metropolitan Life Insurance Company has been studying the effect of the inhalation of asbestos dust by employees in plants in the United States and the Province of Quebec engaged in mining asbestos fiber and manufacturing asbestos products.

In 1929, the American asbestos industry was practically uninformed of the health hazard associated with asbestos dust, although a few British articles had been published describing cases of asbestosis contracted in English plants. In 1927, Cooke and Hill[1] and McDonald[2] gave the first detailed description of what are known as "asbestosis bodies." Asbestos fibers as long as 360 microns were described as occurring in the lung tissue of asbestos workers.

We, therefore, made an effort to distinguish asbestos fibers in our collected air samples and, while we used the impinger method of sampling for the determination of dust counts or concentrations, we also collected a large number of samples with the electric precipitator[3] for examination of physical structure and determination of particle sizes. We were, however, unsuccessful in finding much fibrous material in the air-borne dust and very few of a length greater than 50 microns and practically none of the 360 micron size. We found that 50% of the dust was less than 2.5 microns in the longest diameters while 97% was less than 10 microns. These particles are of the same dimensional sizes as those encountered generally in industrial plants.

Later Fulton[4] and his associates reported that not more than 3% of the air-borne plant dust was greater than 10 microns in the longest diameter which agrees with our findings, although he had surveyed only one of the dozen plants and mines studied by us. Recently the U. S. Public Health Service[5] issued a comprehensive report on the asbestos textile industry covering one of the plants we had previously surveyed, but also many others in other geographical locations. In their survey they took impinger samples for dust counts in order to evaluate the degree of exposure of employees engaged at various operations. On page 23 of this report the following statement is made:

"The relatively low percentage of fibers in suspended dust explains the small number of fibers observed while making dust counts of impinger samples." They determined the percentage of fibers by means of samples collected with the Owens jet dust counter, while Fulton made his fiber deter-

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minations on electric precipitator collected samples.

Recent work published by Gardner[6] indicates that chrysotile fibers less than 3 microns is no more active than the silicate serpentine which has the same chemical composition but which is massive rather than fibrous in structure. He states that by inhalation, chrysotile, ground to such fineness that its fibrous structure is no longer recognizable, has produced no fibrosis in guinea pigs after a year's exposure. All his observations suggest a mechanical rather than a chemical form of irritation, also that the reaction to asbestos is restricted to the lungs because only these organs possess the proper structure and physiological activity to permit friction with a stiff fibrous foreign body.

Recently, the electrostatic dust collector has been placed on the market. This device employs a combination of ionization and electric precipitation in entrapping dust. It is highly efficient in entrapping fine dusts and fumes. It was, therefore, considered advisable to study its efficiency, as compared with the impinger, in determining asbestos dust with the object of distinguishing fibers.

While cotton is used in the manufacture of asbestos textiles, no attempt was made to differentiate between cotton and asbestos fibers. The U. S. Public Health Service[5] in their study were unsuccessful in distinguishing individual types of fibers.

In our study the standard impinger method of

TABLE I.

Preparation Department	Impinger Sampling	M.P.C.F.			Electrostatic Precipitator Sampling	M.P.C.F.		
Sample No.	Cu. Ft. Air Sampled	Total Dust	Fibers	% Fibers	Cu. Ft. Air Sampled	Total Dust	Fibers	% Fibers
1	58	8	.40	5.0	180	4	.40	10.0
2	46	5	.10	2.0	144	4	.30	8.0
3	45	3	.08	3.0	180	3	.30	10.0
4	56	4	.4	10.0	144	4	.30	8.0
5	44	2	.03	2.0	129	5	.40	8.0
6	56	5	.07	1.0	225	6	.50	8.0
7	38	3	.20	7.0	135	6	.50	8.0
8	36	3	.70	21.0	135	4	.50	12.0
Average	47	4	.30	6.0	159	5	.40	9.0

Carding Room	Impinger Sampling	M.P.C.F.			Electrostatic Precipitator Sampling	M.P.C.F.		
Sample No.	Cu. Ft. Air Sampled	Total Dust	Fibers	% Fibers	Cu. Ft. Air Sampled	Total Dust	Fibers	% Fibers
1	42	2	.1	5.0	135	2	.1	5.0
2	42	2	.1	5.0	135	2	.1	5.0
3	44	2	.2	10.0	135	4	.4	10.0
4	42	3	.1	3.0	135	3	.3	10.0
5	44	3	.1	3.0	135	2	.1	5.0
6	44	2	.3	15.0	135	3	.4	13.0
7	44	2	.1	5.0	135	4	.3	8.0
8	37	2	.2	10.0	114	3	.4	13.0
9	36	2	.1	5.0	114	3	.2	7.0
10	52	1	.1	10.0	162	2	.2	10.0
11	45	3	.3	10.0	135	4	.3	8.0
Average	43	2	.2	7.0	134	3	.3	9.0

Mule Spinning	Impinger Sampling	M.P.C.F.			Electrostatic Precipitator Sampling	M.P.C.F.		
Sample No.	Cu. Ft. Air Sampled	Total Dust	Fibers	% Fibers	Cu. Ft. Air Sampled	Total Dust	Fibers	% Fibers
1	29	3	.1	3.0	90	4	.5	13.0
2	34	3	.2	7.0		No sample		
3	34	3	.2	7.0	93	4	.6	15.0
Average	32	3	.2	6.0	92	4	.6	14.0
				SPOOLING, TWISTING & WINDING				
1	34	3	.1	3.0	135	6	2.0	33.0
2	44	3	.1	3.0	135	6	2.0	33.0
3	36	2	.1	5.0	135	4	.4	10.0
Average	38	3	.1	4.0	135	5	1.5	25.0

Weaving	Impinger Sampling	M.P.C.F.			Electrostatic Precipitator Sampling	M.P.C.F.		
Sample No.	Cu. Ft. Air Sampled	Total Dust	Fibers	% Fibers	Cu. Ft. Air Sampled	Total Dust	Fibers	% Fibers
1	44	3	.1	3.0	135	4	.3	8.0
2	34	1	.1	10.0	135	3	.3	10.0
3	44	3	.1	3.0	135	4	.4	10.0
5	46	3	.4	13.0	135	2	.3	15.0
6	44	1	.1	10.0	135	1	.2	20.0
Average	35	2	.1	5.0	135	2	.3	11.0

TABLE II.

	% Fibres Metropolitan Findings Impinger	Electro.	U.S.P.H.S. Findings Owens Jet Dust Counter
Mule Spinning Department	6	14	
Preparation Department	6	9	1 - 8
Carding Department	7	9	7
Spooling, Twisting and Winding	4	25	5
Weaving	5	11	12 - 26

sampling was used with an air ejector to provide suction. Samples were taken simultaneously and at the same locations and at the same elevation with an electrostatic precipitator. The impinger samples were diluted to the required volume and the electrostatic precipitator samples were washed into a standard volumetric flask and diluted to an equal volume in preparation for counting. In some instances further dilution on one or both duplicate samples was necessary where too heavy a concentration was encountered.

Counting was done by the light field method for total dust and for particles distinguishable as fibers. Both factors were recorded. Counts were made immediately after sampling in order to avoid clumping and solution of particles in the case of the impinger samples.

Samples were taken at representative operations throughout the plant and the following tables enumerate the findings.

It will be noted that from three to four times the volume of air was sampled in taking electrostatic precipitator samples, as compared with duplicate impinger samples. Average total dust concentrations agree for both methods of sampling in the preparation, carding, mule spinning and weaving departments.

Spooling and twisting are done in the same room adjacent to looms, while the winding is done in a room next to the mule spinning frames. Pollution from these adjacent operations may account for the variation in the total dust counts in these samples. There is also the possibility of the number of samples not being sufficient to eliminate personal or other discrepancies.

It is interesting to note the increase in the number of fibers counted in going from the preparation department, through carding, spinning, twisting, into the final operation of weaving.

The U. S. Public Health Service gave percentage of fibers at crushing and picking operations only in the weave room and no figure for spinning. From our observation of the type of operation, we believe more fibers may be thrown off in mule than in ring frame spinning. We found more fiber in the spooling, twisting, and winding than the U. S. Public Health Service reports, although they report on twisting only.

Again we fall close to the U. S. Public Health Service average of fibers in the weaving department. Of course, we must consider the three methods of sampling, in comparing these figures.

Conclusions

ALTHOUGH this report is limited to a relatively small number of comparative samples, it may be concluded that in the determination of asbestos dust in asbestos textile mills:

1. The impinger and electrostatic methods of sampling agree in the determination of total dust concentrations.

2. The electrostatic precipitator does entrap more fibers than the impinger. There is, however, the question of any hygienic significance in the increase determined.

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Physiologic Effects

—*of Hot Atmospheres*—

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WITH the growing interest in the well-being of industrial workers and the extension of so-called hot industries, the physiological effect of hot atmospheres on man is becoming of increasing importance. Probably the earliest recognition of the effect of heat on workers was in certain branches of the mining industry where workers penetrated in the earth's interior to high temperatures, produced either directly or indirectly by volcanic action or due to the adiabatic heat of compression resulting from the increased barometric pressure. Considerable early information

is found on the subject, mostly from the point of view of industrial workers including miners, as well as occupants in places of assemblage having improper ventilation. Some of these developments are reviewed by Fleisher[1] and others in a recent treatise and will not be repeated here.

In 1920 the U. S. Public Health Service and the U. S. Bureau of Mines, being interested in this subject as pertaining to the mining industry, joined forces in a comprehensive study with the Research Laboratory of the American Society of Heating and Ventilating Engineers, which was interested in all the phases of the effects of atmospheric conditions on the health and comfort of man. This work has since been continued in one form or another. Initiated at an earlier date, and later carried on simultaneously, extensive studies covering various phases of the subject were made also in England, under Leonard Hill, Dr. Vernon, Dr. Bedford, and others.

Contrary to the belief of the layman, the damage due to high temperature almost always arises from heat generated within the body by metabolic processes rather than from heat imparted to the body from without. That is, the high temperatures of the atmosphere and surroundings usually serve merely to interfere with the elimination of the heat produced within the body, thereby causing the temperature rise; in relatively few instances are conditions encountered in which the high temperature of the atmosphere or surroundings is severe enough to result in actual transfer of heat from the atmosphere or surrounding surfaces to the body.

As mentioned previously, it is through the natural processes of life, or metabolism, that heat is generated in the body. An average-size male adult (i.e., a 5-ft., 9-in. man, weighing 160 lbs.) seated at rest in a comfortable atmosphere produces about 400 Btu of heat per hour; with increased physical activity this rate of heat production becomes 600 Btu for a clerk moderately active standing at a counter, 1500 Btu for a man bowling, and a value variously estimated from 3,000 to 4,800 Btu for maximum human exertion. This rate of heat production for a person seated at rest varies directly as the surface area of the body, following according to physical law based upon the fact that the chief purpose of metabolism for a person seated at rest is to maintain body temperature at around 99°F. Under any condition the heat generated by metabolic processes must be dissipated in order to avoid a rise in body temperature. A person performing physical work transforms some of the energy from metabolism into such work directly, which need not be accounted for by dissipation of heat. However, since human bodies are very inefficient as engines (having an efficiency variously estimated at from 5 to 15%) the amount of energy dissipated by this means is never large, and a man engaged in maximum physical exertion must therefore dissipate approximately 4000 Btu of heat to his atmospheric environment per hour in one form or another.

This heat is dissipated in accordance with four well-defined physical principles.

1. By direct radiation from the clothed body to surrounding surfaces in view of the body surface. This transfer follows the laws of Stefan-Boltzman and varies as the difference of the fourth powers of the radiating and receiving surface temperatures; generally, approximately 40% of the total heat dissipated from a person at rest is ascribed to radiation.

2. By direct contact, whereby the air coming into contact with the surfaces of the clothed body takes up heat. This is generally spoken of as convection loss and follows the usual convection laws based upon the difference in temperature of the air and the surfaces of the clothed body. Physiologically, the body has little or no control over this source of heat loss, although theoretically there may be some minute control due to the fact that in overheating there is some rise in skin temperature. However, this control is negligible.

3. By air movement, which is related to convection loss mentioned above, and which serves to increase the heat loss over that resulting from only normal convection currents. Even in the normal living quarters of man, air movement is an important factor in heat dissipation. What is ordinarily called "still air" in a room is really air moving wth velocities from 5 to 15 fpm (classified as stagnant), to velocities of 25 to 40 fpm (frequently referred to as "fresh air" or non-stagnant air), to velocities of 60 fpm or greater, which are often recognized as drafts under certain conditions. Obviously, increased heat loss due to air movement is not subject to physiological control to any measurable extent, but depends upon purely physical laws.

4. By evaporation of perspiration from the body and moisture from the respiratory tract, through which method the human body does exercise physiological control of heat loss and thereby its temperature. The heat thus dissipated is equal to the latent heat of vaporization of the moisture and is referred to as latent heat loss, compared with sensible or that loss by the first three avenues mentioned above. Sensible heat loss from the human body raises the temperature of the environmental air while latent heat loss raises its humidity.

Under usual environmental conditions heat loss by radiation and by convection, either with or without mechanical air movement, are proportional to each other and difficult of separation. This is the case for conditions in which the wall surfaces in view of the person are at or near the environmental air temperature. There are, of course, notable exceptions, such as working conditions in steel mills and around furnaces where the surfaces in view of the worker may be at elevated temperatures; or, other rare cases in refrigerating plants where the surfaces may be considerably cooler than the environmental air. The magnitude of the effect of radiation from hot surfaces is only generally understood, but several investigations of various phases of this subject are now under way at the Research Laboratory of the American Society of Heating and Ventilating Engineers, at the Pierce Foundation Laboratory at

Yale, and by Dr. Bedford and others in England. Further, it should be understood that radiation effects are entirely independent of the condition of the environmental air, excepting as environmental air automatically affects the temperature of such surfaces.

Leaving out for the moment the effect of radiation from hot surfaces, it will be noted that there are three conditions of the atmosphere having a paramount effect on heat dissipation from the human body; namely, temperature, moisture content and air movement. The relative effect of these three factors is readily illustrated by Fig. 1 and 2, developed and used by the air conditioning engineer, not only to make readily available the thermodynamic requirements for change in air conditions, but also to be used as an index of comfort conditions resulting from combinations of temperature, humidity and air motion.

In these charts, the dry-bulb temperature is plotted as the X-axis and the moisture content in grains per pound of dry air as the Y-axis. The family of lines curving upward to the right indicate the relative humidity in percentage of satura-

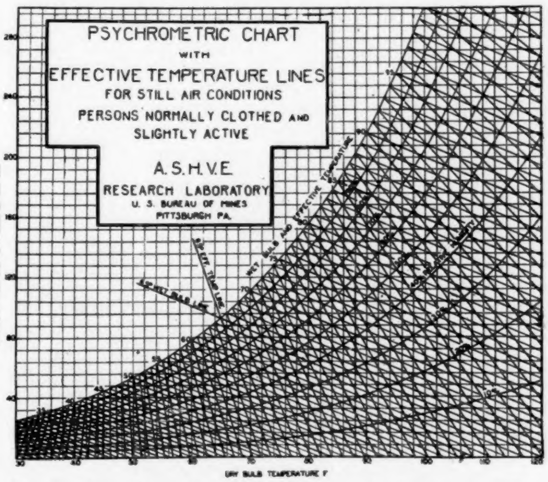

Fig. 1. Psychrometric chart having included a wide range of effective temperatures.

tion. It will be noted that at 70°F. (the generally accepted winter heating temperature) one pound of dry air may have associated with it about 112 grains of moisture for saturation. If the air contains only one-half this amount, or 56 grains, the relative humidity is 50%. On the other hand, 85° air has associated with it 184 grains for saturation, and 100° has 300 grains for saturation. The lines sloping obliquely to the right indicate the wet-bulb temperature of the air, or the temperature shown by a thermometer the bulb of which is covered with a wet wick and over which the air is moving at a high velocity. Wet-bulb and dry-bulb temperatures of the air are readily indicated by a sling psychrometer. This much of the psychrometric chart in Fig. 1 was developed prior to 1920.

While for some time it had been recognized that a high relative humidity at a given dry-bulb temperature in the summer time made a person feel warmer, there were no data available giving the magnitude of these effects. Through a comprehensive study[2,3] the set of curves sloping abruptly to the right, indicated as "effective temperature" lines, were published by the A.S.H.V.E. in 1923. These effective temperature lines are lines of equal feeling of warmth for persons normally clothed and seated at rest; and insofar as has been determined with any degree of accuracy these effective temperature lines are accurate indices of not only a person's feeling of warmth, but also of most of his physiological reactions. For indoor winter heating conditions in the United States, 66° effective temperature is accepted as giving ideal comfort to most people. Under summer cooling conditions throughout most of the United States, effective temperatures ranging from about 69 up to 72 or 73° give optimum comfort over a wide range of relative humidities.

In Fig. 2 is well brought out the effect of air movement on a person's feeling of warmth. It will be noted that for moderate atmospheric conditions air movement makes any condition feel cooler, or in other words, a given effective temperature line

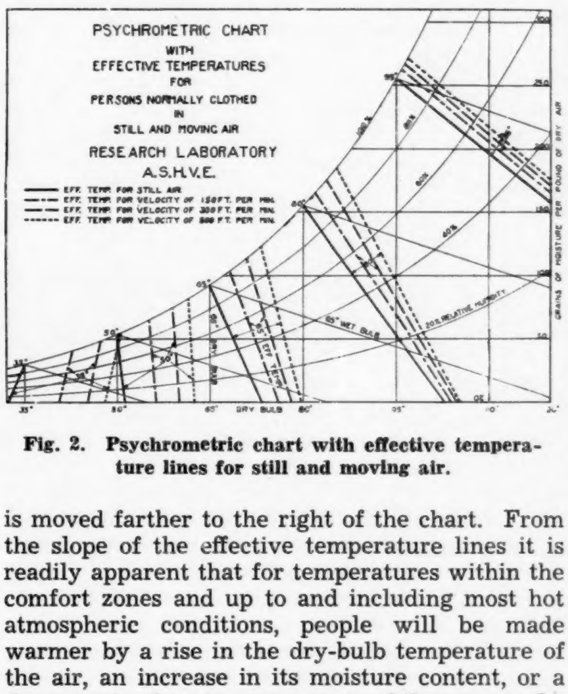

Fig. 2. Psychrometric chart with effective temperature lines for still and moving air.

is moved farther to the right of the chart. From the slope of the effective temperature lines it is readily apparent that for temperatures within the comfort zones and up to and including most hot atmospheric conditions, people will be made warmer by a rise in the dry-bulb temperature of the air, an increase in its moisture content, or a decrease in the air movement; while conversely, they may be made cooler by lowering the dry-bulb temperature, decreasing the relative humidity, or increasing the movement of the air. With extremely high temperatures, the effect of air movement is reversed. The tremendous influence of temperature, humidity and air movement on heat dissipation from the body is illustrated by a comprehensive study of the subject,[4,5,6,7] made cooperatively by the Research Laboratory of the A.S.H.V.E., and the U. S. Bureau of Mines.

In Figs. 3 and 4 are shown, respectively, the rate of heat production within the body, and the total rate of heat loss from the body through an effective temperature range including hot atmospheres.

It will be noted that the heat production remains minimal and equal to the heat loss from approximately 60 to 90° effective temperature. For lower temperatures a higher metabolic rate, or higher rate of heat production, is required to maintain body temperature; while for effective temperatures above 90° there is an increase in the rate of heat production and a rapid decrease in the rate of heat loss. The increase in rate of heat production at lower temperatures is a good example of compensation in heat production in order to maintain body temperature. The increase in heat production for high temperatures when the body can no longer maintain temperature equilibrium by heat dissipation represents a breakdown in control.

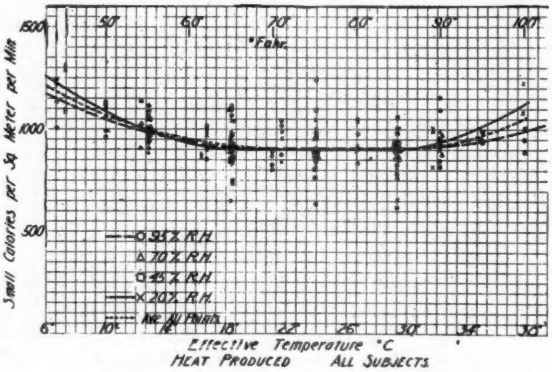

Fig. 3. Relation between heat production in the human body and effective temperature.

The differentiation in the total rate of heat loss for persons at rest in atmospheres of 65, 75, and 85° E T, which conditions may be accepted respectively, as those approximating ideal comfort with winter heating, slightly warm for comfort in summer cooling, and decidedly hot for comfort, are shown in Figs. 5, 6, and 7. In these charts the total rate of heat loss, the heat loss by radiation and convection combined (or the sensible heat loss), and the heat loss by evaporation (or the latent heat loss), are each plotted against dry-bulb for the given effective temperature. In each case the total rate of heat production within the body, or the total rate of heat loss from the body, is constant; while the radiation and convection losses decrease with increase in dry-bulb temperature and the latent heat loss increases with dry-bulb temperature.

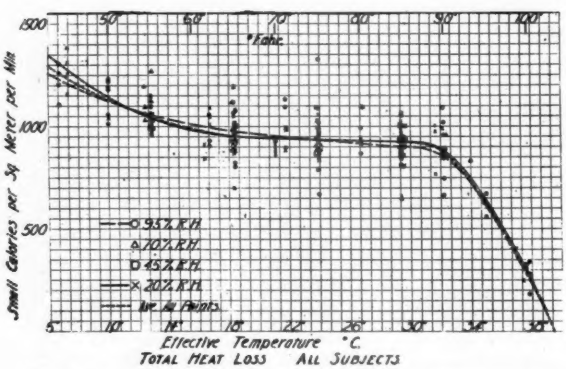

Fig. 4. Relation between heat loss from the human body and effective temperature.

Of considerable interest is the relation between the total rate of heat loss and that loss by radiation and convection on the one hand, and by evaporation of perspiration on the other. For winter comfort conditions, or approximately 65° effective temperature, radiation and convection losses constitute about ¾ and evaporation ¼ of the approximately 400 Btu total heat loss per hour, at a relative humidity of 50%. At 75° effective temperature, or a condition which is a little warm for summer cooling comfort, the total loss remains at 400 Btu, but this is divided equally between loss by radiation and convection and loss by evaporation, for approximately a 50% relative humidity condition. On the other hand, at 85° effective temperature, radiation and convection combined varies from positive 37.5% to negative 56%; while evaporation still takes care of the varying amount necessary to maintain body temperature, changing from the minimum of 62.5 to a maximum of 156% of the total rate of heat production. In other words, with 85° effective temperature and a high dry-bulb of over 100°F., the body actually gains heat from contact with the warm air; but it is still able to lose by evaporation not only the 400 Btu which is being produced by metabolism, but also that additional heat gained from contact with the air. These facts well demonstrate the wide adaptability of the human mechanism and also indicate a tremendous task on the heat regulatory mechanism which must be understood by the industrial physician, who would become interested in the effect on men working in hot atmospheres of widely different moisture contents.

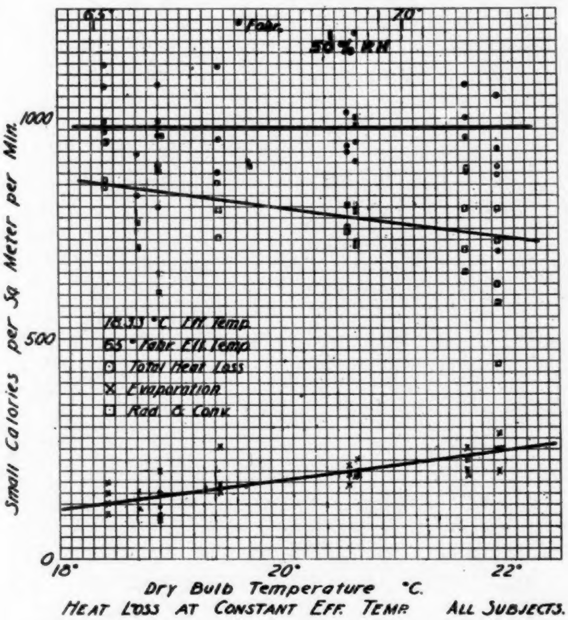

Fig. 5. Relation between heat loss from the human body at 65° effective temperature and dry-bulb temperature.

As a further indication of the effect of more severe conditions it might be pointed out that with 90° E T, which may be accepted as the hottest condition in which men may work for a few hours without violently harmful effects (which may cover a range of 91°F dry-bulb and 95% relative humidity to 124°F at 10% relative humidity), radiation and convection may account for from 60 Btu loss from the body at saturation, to 325 Btu gain, while evaporation may range from 280 Btu

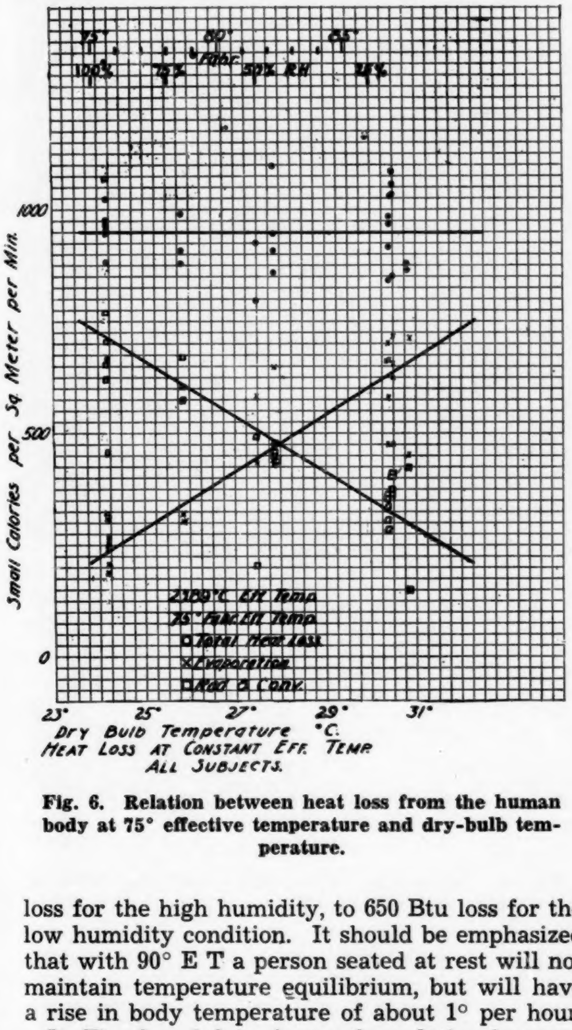

Fig. 6. Relation between heat loss from the human body at 75° effective temperature and dry-bulb temperature.

loss for the high humidity, to 650 Btu loss for the low humidity condition. It should be emphasized that with 90° E T a person seated at rest will not maintain temperature equilibrium, but will have a rise in body temperature of about 1° per hour.

In Fig. 8 and 9 is shown the relation between effective temperature of the atmospheric environment and both the rate of rise in body temperature and the pulse increase of persons at 30, 60 and 100% relative humidity, while Fig. 10 gives the same data plotted against the dry-bulb temperature of the atmosphere. It will be observed that whereas complete separation of the curves results when plotting against dry-bulb temperature, quite satisfactory correlation exists when plotted against effective temperature, verifying the statement above that effective temperature may be accepted as not only an index of a person's feeling of warmth, but also of most of his physiological reactions to hot atmosphere.

Figs. 11 and 12 are taken from a study concerning the effect of hot atmospheres and high relative humidities on the physiological reactions of workers, as conducted last summer by the A.S.H.V.E. in cooperation with the U. S. Bureau of Mines, and the Department of Industrial Hygiene of the School of Medicine, University of Pittsburgh. These studies were designed to indicate the effects of hot atmospheres on workers engaged in extremely light work but requiring alertness. The study was made largely on college students, there

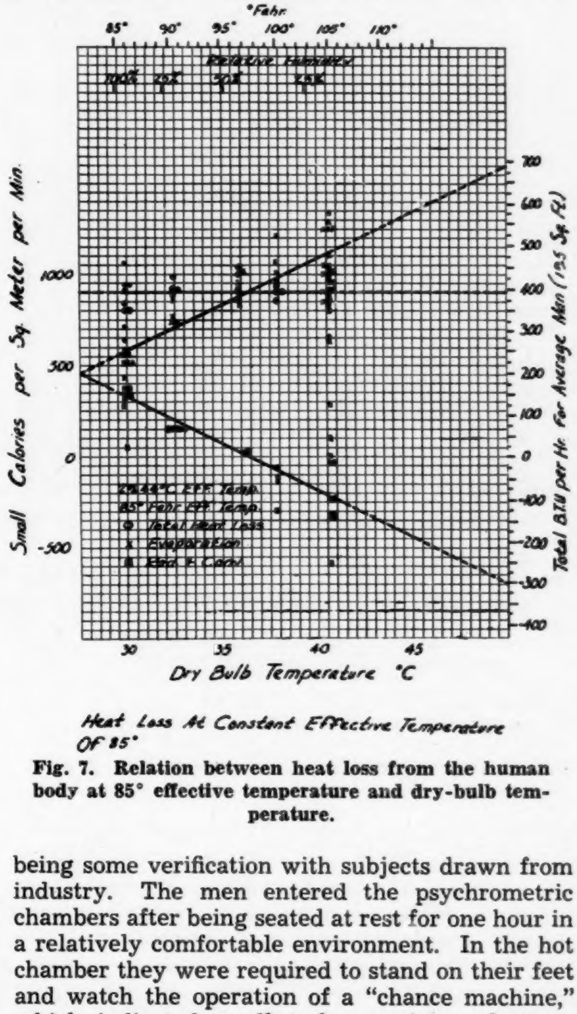

Fig. 7. Relation between heat loss from the human body at 85° effective temperature and dry-bulb temperature.

being some verification with subjects drawn from industry. The men entered the psychrometric chambers after being seated at rest for one hour in a relatively comfortable environment. In the hot chamber they were required to stand on their feet and watch the operation of a "chance machine," which indicated small tasks requiring alertness but no greater physical exertion than throwing dice or moving small weights about a 3 by 6 ft. table. This type of work was assumed to simulate many types of occupation in modern industry, where no great physical exertion is required but where the machine attendant must be alert to detect and correct defects in operation or performance.

Some of the physiological reactions of one of the subjects in a test at 90° E T and 75% relative humidity are given in Fig. 13. The rise in rectal temperature and decrease in vital capacity are plotted against time in the lower part of the chart. His change in pulse rate, decrease in weight, the degree of perspiration on his body and forehead, his increase in leucocyte blood count, and feeling of warmth are plotted in the three upper sections

of the chart. It will be noted that for this atmospheric condition there was a persistent change in all of the observed physiological reactions.

In Figs. 14 and 15 the rise in body temperature at three different relative humidities after three hours exposure are plotted against effective temperature and dry-bulb temperature, respectively. It will be noted that when plotted against effective temperature, the curves for the three humidities

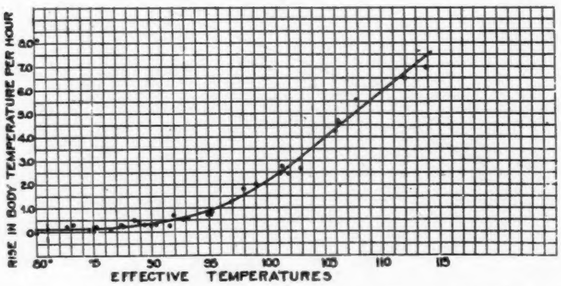

Fig. 8. Curve showing relation between effective temperature and rate of rise in body temperature, at relative humidities of 30, 60, and 100%.

coincide, while when plotted against dry-bulb temperature there is a marked separation of the three curves. The curves in Fig. 14 show that there is a slight rise in body temperature for workers performing these light tasks as soon as the effective temperature rises above 80°, with

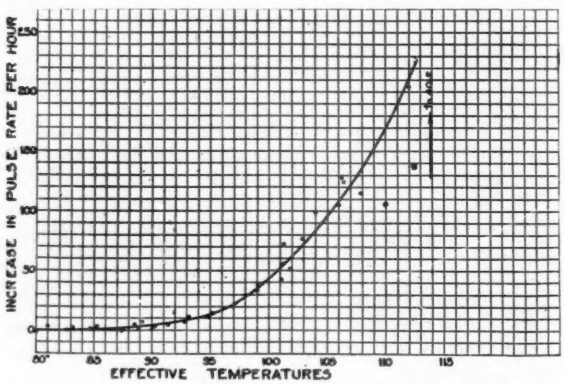

Fig. 9. Curve showing relation between effective temperature and rate of pulse increase, at relative humidities of 30, 60, and 100%.

1½° rise in three hours occurring in an atmospheric condition of 92° E T. The relation between the increase in pulse rate and effective temperature after three hours exposure is plotted in Fig. 16. This shows an increase of a little less than 10 beats a minute after three hours exposure in 85° air and an increase of slightly more than 40 beats a minute after three hours exposure in 92° air.

Vital capacity and leucocyte count are plotted, respectively, in Figs. 17 and 18. The change in vital capacity while positive is not much greater than the individual variations. Increase in leucocyte count, however, shows a very pronounced effect, as was shown also in a recent study of fever therapy applications.[8] This leucocyte increase brings up an interesting question regarding the relationship in industry between air conditioning and health, for both body temperature and white cell increases are protective reactions and are more prominent when infection has invaded the body. It has been found that continued exposures in poorly ventilated areas with extremely high effective temperatures cause physiological changes characterized by elevation of body temperature and increase in white cells. It is quite conceivable to believe that there would come a time when the constant daily demand on the body for increases in temperature and white cells might produce a state of exhaustion or fatigue which in turn might pre-

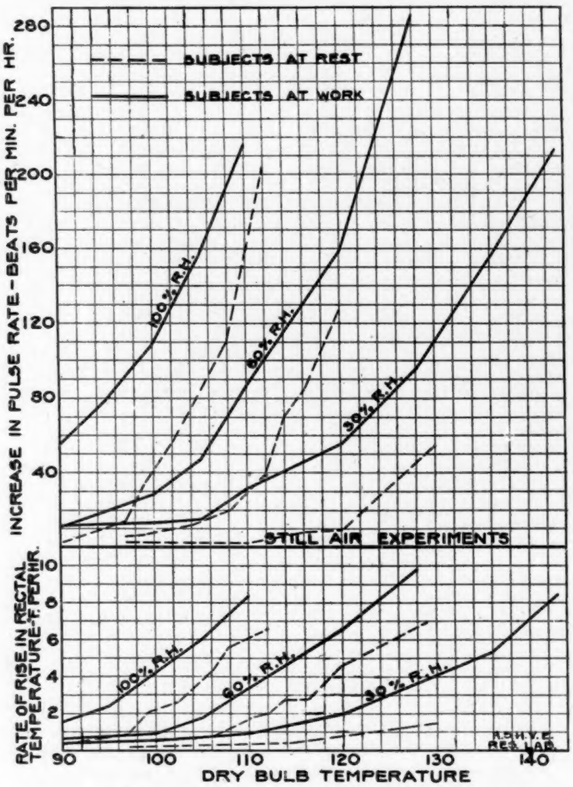

Fig. 10. Charts showing changes in body temperature and pulse rate for three different relative humidities.

vent the throwing of more cells into the circulation when the need became acute; if this state of exhaustion were to continue, the status of the body might be dangerous if an infection were contracted, and the body were then unable to produce cells and temperature increases to help overcome it.

However, it appears that working in hot atmospheres would be less dangerous in cool months because the normal relationship between environmental conditions and body responses would obviate the necessity for stimulation of physiological processes just described. This contention is based on a smaller mass of data obtained in a similar study carried on by the Research Laboratory during the past winter. A comparison of the summer and winter studies indicates that the summer studies produced white count increases somewhat lower than those for the winter study. This would appear to be characteristic because of acclimatiza-

tion to hotter surroundings in the summer; further, it is believed that the cooler weather permits better return to normal physiological conditions since lower outside temperatures prevent the white cell increases that ordinarily occur during the hot summer weather. These comparative deductions are substantiated to some extent by the fact that although there are fewer infections in hot months, the death rate from those infections are proportionately considerably higher than in cooler months, resulting probably from the relationship between the environmental temperatures and the acclimatization resulting in exhaustion of physiological processes.

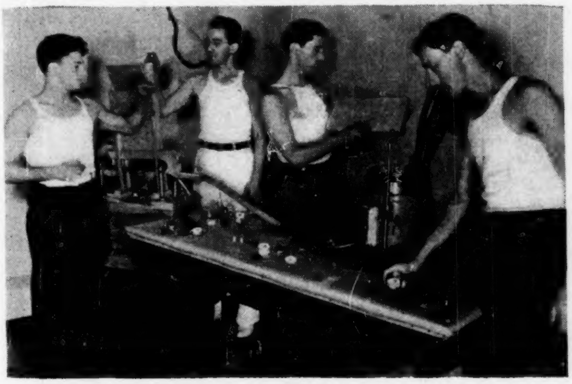

Fig. 11. Scene in hot room during test showing the various activities of the subjects: (A) Taking body temperature; (B) Dropping ball into chance machine; (C) Recording pulse and body temperature; (D) Act of shifting weights.

The measurement of vital capacity in the laboratory study has no particular significance, except that its inclusion may lead to new trends of thought. Vital capacity is that volume of air that can be expelled by the most vigorous expiratory effort after the deepest possible inspiration, and is normally about 3500 cc. This measurement is an indication of respiratory efficiency, and shows values lower than normal after longer periods of time at higher effective temperatures. The small change would appear to be of little importance except that lowered vital capacities in hot atmospheres might indicate physiological changes. Assuming any mild pulmonary ailment to be present, the fatigue produced by hot atmospheres would exaggerate the deviation from normal, and lower values would definitely result. Excluding pulmonary pathology, fatigue is the most probable cause of the lowered vital capacity, and it would appear that each routine physical examination of new and old workers should include these vital capacity determinations because frequently, obscure ailments may be revealed before more prominent signs present themselves.

The use of salt in industry to prevent "heat disease" has been clearly demonstrated by many competent investigators in the past several years. From research studies in fever therapy by the School of Medicine, University of Pittsburgh, there is evidence to show that the administration of salt is helpful and should be increased as the work day progresses. In other words, the amount of salt taken during the first few hours of work may not be sufficient for the remaining hours, since in most instances the weather becomes hotter; therefore, the body becomes subjected to high temperatures for a number of hours, with the result that the requirements would be greater to maintain a chloride balance more closely approximating the normal. From fever therapy studies this fact is borne out when lower chloride content of the blood is shown as the treatment progresses, despite the fact that the temperature

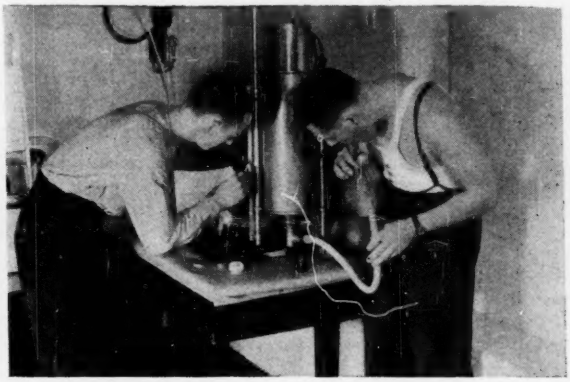

Fig. 12. Observer making notes while subject breathes into vital capacity machine.

is no higher than the previous observation. This finding may be applied to conditions in industry, although the conditions are considerably less severe than those experienced by the fever therapy patient. Other data show an increase in systolic and a decrease in diastolic blood pressures after three hours' exposure. This deviation from normal would have been considerably greater if the subjects had been in a state of exhaustion while exposed to the extremely hot temperatures maintained. With exposure to heat there is at first a slight increase in both systolic and diastolic pressures; with continued exposure, heat produces dilatation of the blood vessels resulting in a decreased diastolic, but an increased systolic pressure, which is necessary to supply the enlarged capillary vessel bed. However, if the hot environment persists, there is a further fall in diastolic pressure; and if fatigue or exhaustion ensues, a corresponding fall in systolic would occur, which might produce even death if permitted to continue indefinitely.

Fig. 19 shows metabolic rates for different persons engaged in different activities. The basal determinations are for subjects engaged in the recent studies at the Laboratory reported above, taken in the morning after fasting; while the "light work standing" are for the metabolic rates of the men engaged in their designated activity about the chance machine in these studies.

It was not so much the purpose in the studies referred to above to determine limitations in

harmful effects which may be allowed among workers in hot industries, but rather to determine and record the relationship between their physiological reactions and the atmospheric conditions. To determine just what the limitation in such reactions should be in the case of a given worker should be left to the decision of the industrial physician. In this connection, the work should be continued further to a point at which a chart may be established from which the relation between the allowable physiological disturbance, time of employment in the hot condition, and the

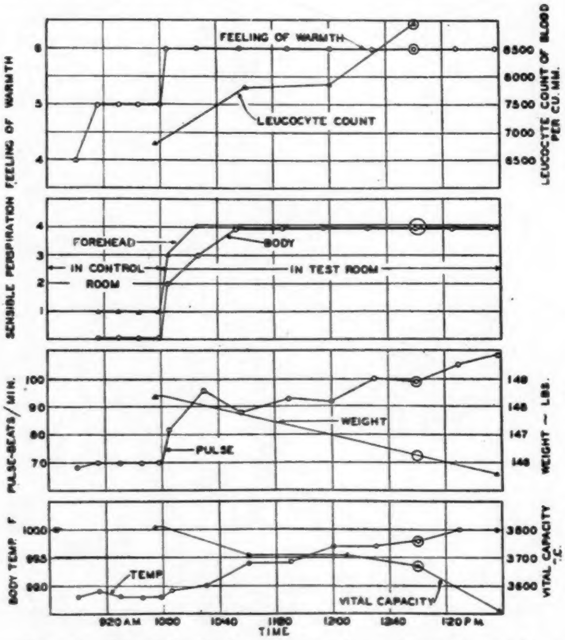

Fig. 13. Physiological response of a subject at rest in control room and while working in an air condition of 90° ET and 75% relative humidity.

physical exertion may be determined. While the amount of data at this time can in no sense be construed as sufficient to establish these relationships, the data so far collected and gleaned from earlier studies give some indication of the form which such a chart will take. This is indicated in Fig. 20 in which the metabolic rate in calories per sq. meter per hour is plotted as ordinate and the effective temperature of the air condition as abscissa for various rises in body temperature and increases in pulse rate after various time exposures. The results of the study at light work giving a metabolic rate of about 76 cal. per sq. meter per hour are fairly comprehensive and satisfactorily establish the location of the curves for this rate of activity. A much smaller mass of data from an earlier study, when the purpose of this investigation had not yet been formulated, give similar reactions for persons seated at rest, or for a metabolic rate of 45 cal/sq. meter/hr.; and a still lesser mass of data for men pulling weights in what was then classed as heavy work, gives a metabolic rate of 145 cal/sq. meter/hr. Before this chart can be useful, the data "at rest" and data at "heavy work" must be verified and additional studies must be made for intermediate rates of work.

Since such studies have already indicated rather conclusively that the physiological reactions are governed largely by both the metabolic rate, or the total rate at which the heat must be dissipated from the body, and the effective temperature of the atmosphere, it would seem probable that the investigation could be limited to a relatively few rates of activity, provided the metabolic rates for the same were accurately established. If this principle may be accepted, then such a chart

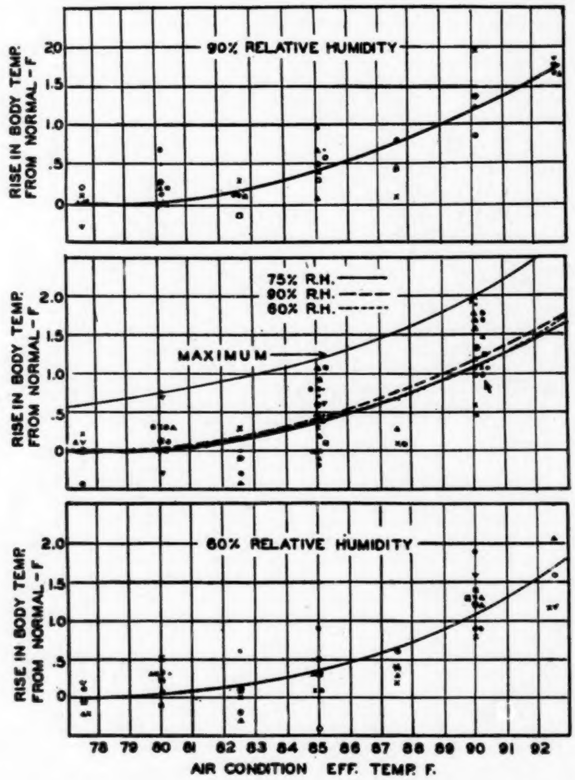

Fig. 14. Relation between rise in body temperature from normal during three-hour exposure and the effective temperature of the air condition in the test room for 60, 75, and 90% relative humidities. Test points for individuals apply to heavy solid curves.

properly developed may be used for predetermining the relationships for any other physical activity, provided the metabolic rate for the same has been established.

These future studies should include a consideration of the relation between the violence of each of the pertinent physiological reactions and both the frequency of their occurrence and the general well-being and health of the worker. This would require a comprehensive and probably long drawn out series of investigations, some of which could best be conducted under controlled laboratory conditions, while other studies must be based upon observations of the industrial hygienist in industrial surroundings. In these latter studies it would probably be observed that the frequency of exposure and the number of years

over which such exposures occur would be important. There certainly are no grounds for assuming that even very uncomfortable exposures to high temperatures for short periods of time and at infrequent intervals must be avoided. Certain subjects in the studies referred to above were exposed during the investigations to such severe conditions that their body temperatures frequently rose to 105° while the pulse rate more than doubled, with no apparent serious effect. What the results would have been if such exposures were endured five or six days a week over a period of years is, however, problematical.

It should be kept in the foreground in any continued study that the degree of physical activity in any given occupation, probably as determined by the metabolic rate of the worker, is one of the most important factors involved. The curves and data here presented are for only very moderate rates of work.

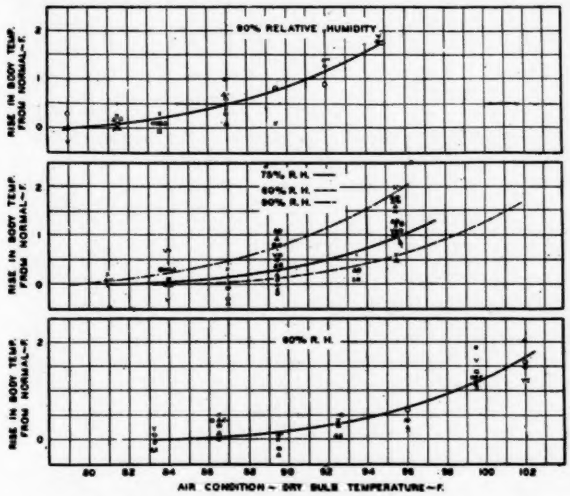

Fig. 15. Relation between rise in body temperature from normal during three-hour exposure and the dry-bulb temperature of the air condition in the test room for 60, 75 and 90% relative humidities. Test points for individual subjects apply to heavy solid curves.

The available means for alleviating damage to the workmen exposed to high atmospheric conditions are varied. The most obvious recourse is to limit the time of exposure. There appears to be no harm in short exposures to very extreme conditions of heat providing no burns or scorching of the skin results, and also if the time of exposure is so limited that the rise in body temperature is not excessive. In this connection, it may be well to point out that rise in body temperature seems to be the one fundamental reaction on which all others depend. This would also seem logical from the purely physical consideration of the problem.

A more expensive means of alleviating conditions is, of course, available in air conditioning, and undoubtedly there are many industrial activities which require such treatment. As mentioned previously, cooling may be had through lowering the dry-bulb temperature of the air, decreasing its moisture content, or, excepting under extremely hot conditions, by increasing the air movement. In very hot conditions the cost of conditioning a large volume of air in order to relieve a small number of workmen may become excessively expensive in certain instances. This would be the case if there were unavoidable dissipation of the cooled or conditioned air, or if large volumes of air had to be supplied for the industrial processes involved or for other conditioning purposes such as elimination of harmful gases, dusts, etc. In such cases, it may be far more economical to apply cooling more directly to the individual concerned or to supply a small volume of air limited to his immediate needs.

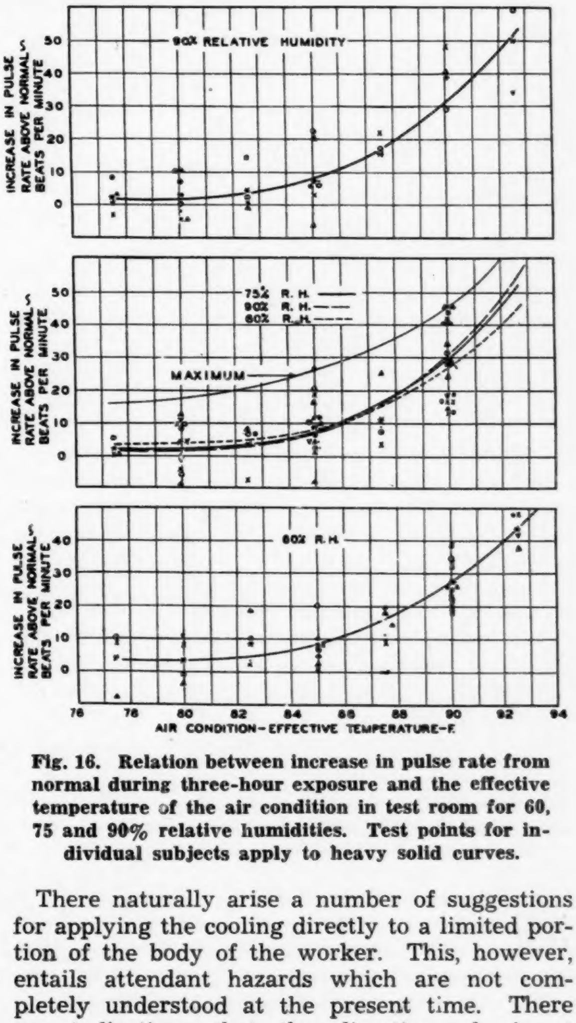

Fig. 16. Relation between increase in pulse rate from normal during three-hour exposure and the effective temperature of the air condition in test room for 60, 75 and 90% relative humidities. Test points for individual subjects apply to heavy solid curves.

There naturally arise a number of suggestions for applying the cooling directly to a limited portion of the body of the worker. This, however, entails attendant hazards which are not completely understood at the present time. There are indications that the directing of air at considerably reduced temperatures against a small part of the body surface area may be accompanied by stiffening of muscle tissues and generally rheumatic conditions. Another possible hazard of localized cooling is the effect that it may have on the temperature regulatory mechanism (analogous to thermostatic control in air conditioning). If there is within the human body such a thermostatic center, and if this center is excessively cooled, undoubtedly the effect would

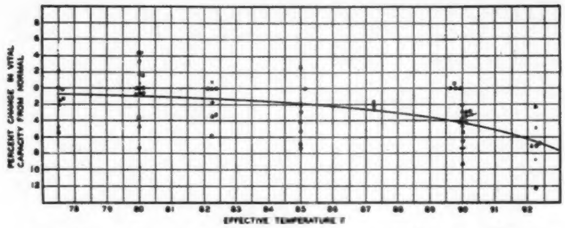

Fig. 17. Per cent change in vital capacity after three hours of work in atmospheric conditions of 60, 75 and 90% relative humidities and the effective temperatures indicated. Curve shows change for the three humidities.

be to call for an increased rate of metabolism. There are claims that this may result from the application of cooling directly to the head, but the evidence on this point is not conclusive. The cooling effect experienced by a worker may be either real and physical, or it may be psychological. The application of a small amount of cooled air to the face or head may give a considerable sense of relief, with at best a very small real reduction in the factors tending to produce a rise in body temperature.

In a number of instances it is probable that an industrial worker may be given the greatest amount of alleviation at lowest cost by clothing him in a loose-fitting garment into which cooled air is blown and allowed to escape at the ankles and neck. If this application is used, care should be exercised in so baffling the air stream as to avoid excessive local cooling at the point where the low temperature air impinges against the body.

In other industrial applications a jet of cooled air may be directed into the sphere where the worker spends a large part of his time. Under such conditions it is apparently best to direct this stream of air so that the worker may either step into, out of, or only partially into it to meet his individual satisfaction. While it cannot by any means be safely stated that such practices are without harm, it is probable that the age-old fear of drafts is an unnecessary deterring factor in the use of this application.

These unusual applications must be accepted as mere suggestions based on a very limited knowledge. However, it is hoped that the increased

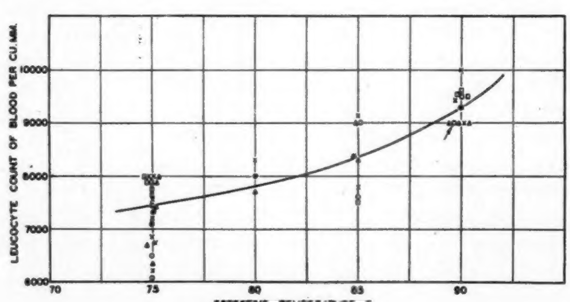

Fig. 18. Change in leucocyte count of blood after three hours of work in atmospheric conditions of 60, 75 and 90% relative humidities and the effective temperatures indicated. Curve shows changes for the three humidities.

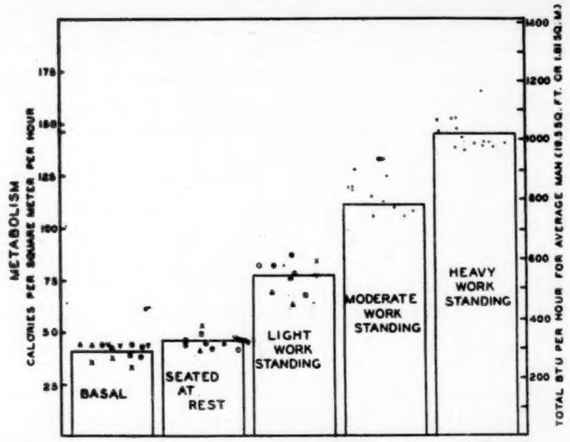

Fig. 19. Relation between metabolic rate and degree of activity.

interest of the industrial hygienist may result in more intensive as well as extensive investigations of its many phases.

[ACKNOWLEDGMENT: This paper results largely from investigations carried on by the Research Laboratory of the American Society of Heating and Ventilating Engineers over a period of years. While some important phases of the subject as presented are the result of recent studies, many

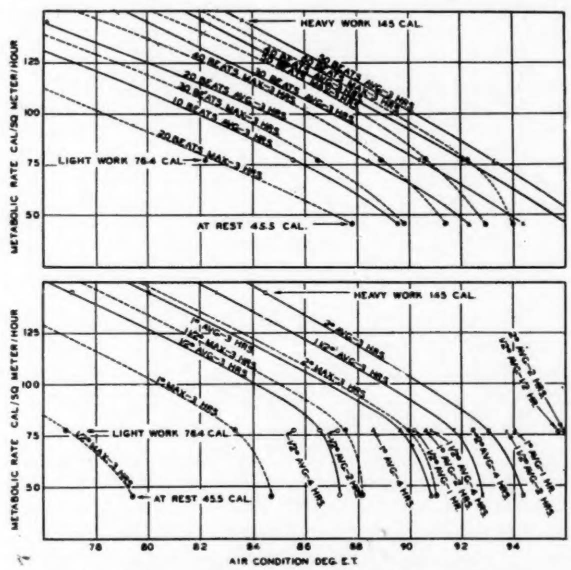

Fig. 20. Relation between the effective temperature of the atmospheric condition and the metabolic rate for rise in temperature of ½, 1, 1½ and 2 deg., and for increase in pulse beat of 10, 20, 30, 40 and 50 beats per minute. Solid line curves represent the average rise in body temperature and the average increase in pulse beats of the average subject. Broken line curves represent the maximum expected rise in body temperature and maximum expected increase in pulse beats for a person physically fit and acclimated for work in hot atmospheres. Maximum curves drawn through points indicating metabolic rates obtained from maximum at rest and light work data are drawn similarly to the curves for the average reaction. Points indicating the position of the curves for the several rises in body temperature in from ½ to 4 hours given for light work only.

other factors contained herein are gleaned from other publications resulting from these studies. For such data the authors are indebted to and give credit to the original publications as referred to in the bibliography, and republished with the permission of the Journal and the Society.]

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Lessons from the History of Lead Poisoning

—*A Review of International Experience*—

LUDWIG TELEKY, M.D.,
Chicago

MUCH can be learned from a brief review of the history of lead poisoning which may be of value in avoiding the continuation of misconception and bringing to light methods which have been successful in reducing the incidence of lead poisoning in many of the industries presenting lead exposures.

As much as 1500 years ago, lead poisoning had been mentioned. As a rule at that time it was caused by the ingestion of lead and its compounds with food and as medicine. Hippocrates described lead poisoning as an occupational disease only in the smelting of metals. Why not in other occupations? I think this is because the worker did not continue uninterruptedly at one operation over any length of time, except the slaves in the mines and in smelting operations.

It was just 100 years ago that a real standard work on plumbism appeared. This book of two volumes totalling 1100 pages was prepared by L. Tanquerel des Planches under the title "Traite des maladies de plomb ou saturnisme" in Paris in 1839. This book which included a discussion of 1213 cases of colic, 752 of arthalgia, 146 paralyses, 72 encephalopathies, and other types continues to be the best and most detailed clinical picture of lead poisoning in existence.

Among the patients suffering from colic, nearly one-third came from white lead manufacturing plants; another third were affected through use of white lead and other lead compounds; the remainder included 54 cases among potters, 52 typefounders and 12 among compositors and printers.

In the following decades, lead poisoning was the typical industrial poisoning and the most widely spread occupational disease. The table shows the decrease of lead poisoning with the increase of other occupational diseases over the years—so far as they were reported or compensated:

OCCUPATIONAL DISEASE TRENDS

		No. of Cases Reported or Compensated	
Country	Year	Lead Poisoning	Other Occupational Diseases
England	1896	1030 reported	20 (3 diseases)
	1908	421 compensated	113 (10 diseases)
	1937	141 compensated	488 (12 diseases)[1]
Germany	1926	3129 reported	209 (7 diseases)
	1935	1295 reported	5494 (19 diseases)[2]
	1935	94 compensated[3]	1161 (19 diseases)

1. Not including silicosis and miners' diseases.
2. Including silicosis.
3. These compensation cases included only those with more than 13 weeks' disability.

This increase of the other occupational diseases is to be accounted for on the one hand by the increase of chemical industry with its numerous new compounds and their increasing use in other industries also; and on the other hand, we have learned to pay attention to occupational disease from other causes and to diagnose these properly, as for instance, silicosis. But how can the decrease of lead poisoning be accounted for and how can we utilize the preventive measures which have been proved to be successful in order to obtain a still further diminution in the development of lead poisoning among workers?

Every lead process has its own history and like other industrial exposures is intimately connected with the technology and economy of the several professions. For example, I have seen *small potteries* where ground lead ore (galena), which is practically insoluble in the body fluids, has been used for glazing and consequently there was no poisoning. The use of red lead was introduced as technical processes became more highly developed. Red lead is very poisonous but in small plants, the same man turns the pots for some weeks and later conducts glazing and burning operation for a few days. The danger is thus reduced by this alternation. But if the workshop develops into a factory and one group of workers is continually occupied in glazing operations, then the exposure to the lead hazard is continuous and the danger is very great—hence protective measures become essential. Protective measures, such as better ventilation and cleanliness, were not sufficient in many

instances, and therefore factory inspectors and the pressure of public opinion brought about the use of more efficacious methods. These were possible with the development of modern furnaces with their higher temperatures. In this way the development of the pottery industry passed through a period of great hazard to one which is nearly satisfactory in many of these plants. It is probable that at the beginning of our observations in England (1900) the danger in pottery was at its maximum, 210 cases being reported in England in 1900. In 1937, only 15 cases were reported.

A similar diminution in the number of lead poisoning cases has occurred in other occupations. In the *painting trade* in some countries, legal prohibition of the use of lead paints in the interior of buildings has diminished the danger—for instance, in Germany, France and other countries according to a Geneva convention. In others (England) stringent regulations for the use of lead paints induced the employer to use other paints. The number of cases dropped in England from 682 in 1914 to 30 in 1937. Lead poisoning in *file cutting* was the effect of the use of a lead bed in cutting. Now the hand work is replaced by machine work. Forty-six cases had been reported in England in 1901, the three last cases were reported in 1920. Since then the lead poisoning of filecutters has disappeared and also a characteristic form of lead paralysis, due to overstraining of the small hand muscles.

There is one trade which has had its own remarkable history: the *printing trade*. Typefounding (but not machine composition) was and is certainly always a dangerous process and formerly was more dangerous because the founded letters were so imperfect that rubling and undercutting were necessary, producing fine dust. But if you consult a textbook, especially an older one, you find among the most dangerous trades not only the typefounders but the *whole* printing trade, especially the compositors and printers. If you look up the statistics of some printer sick-fund you are led to believe that it is a very dangerous work as you see the terrifying number of cases of lead poisoning listed. I myself was the specialist for occupational diseases at the sick-funds for the printing trade in Vienna 30 years ago. But I very rarely saw compositors and printers who had developed lead poisoning. I saw only a large crowd of them sent by physicians with the diagnosis "lead poisoning" but suffering from all other diseases (appendicitis, diabetes, and others). In Germany, the practitioners and the printers and compositors over-estimated the danger at this time. In England, this superstition did not exist. It is of interest that the greatest number of lead poisoning cases in the printing industry in England was 30 in 1908, with only three reported in 1937.

You see, lead poisoning in every single profession has its own history which is determined on the one hand by the technical and economical development of the industry; on the other hand by the laws, rules and regulations of the State and their enforcement under the influence of factory inspection, especially of the medical inspectors who may be well pleased by the work done.

IF THUS the history of the danger of lead poisoning and of its control in the several trades includes much of interest, of which I have only mentioned the high points, the clinical picture of lead poisoning also has its history.

In my activity as specialist for occupational diseases of the Viennese sick-funds, I published in 1908 a paper concerning 45 cases of lead paresis seen in three years. In a greater sphere of activity after the war I have in 10 years seen only a fraction of this number. Legge reports that in the years 1900 to 1904, 577 men showed paretic symptoms, 18.8% of all cases; in 1920 through 1924 there were only 99 such cases, or 7.1% of the total.

During the first years of this century there were medical inspectors, working in practical industrial hygiene, only in England. In other countries, industrial hygiene was in the hands of engineers entirely. These said to some hygienic theorist: Give us one certain infallible sign of lead poisoning. And some hygienist (without clinical experience) thought that the stippled cells would be this sign. German experts especially laid great stress on the stippled cells, while the English (Legge, Goadby, and Oliver) did not give them similar importance.

That stippled cells are to be found in small numbers also in normal blood was soon known and the borderline established. It was overlooked in the beginning that various coloring substances render a different number of stippled cells visible (staining by May Grunwald rendered visible only 41% of those found by staining with Loeffler's methylene blue) and also that the degree of hardening of the blood smears has an influence on the appearance of the punctation.

Furthermore account was not taken of the fact that the irritability of various organs (including the blood-forming organs) is different in various individuals, and that there is ordinarily no one "pathognomic" sign for any sickness that is to be found in all cases of that illness and only in one illness. *In every disease there is a multiplicity of symptoms, "the clinical picture" that is characteristic and renders diagnosis possible.* This truth was forgotten by some on the continent, and I think in America—stippled cells, and more recently, reticulocytes are estimated by some people in the same way. We know today that stippled cells (not reticulocytes) are a very considerable aid in the diagnosis of lead poisoning, but that there are fresh cases of lead poisoning without stippled cells—even though these are very rare, and that there are many very chronic cases without stippled cells. These cells are signs of fresh lead absorption, disappearing as a rule after absorption ceases and in a shorter time than other serious symptoms disappear, particularly those of the nervous and circulatory systems. These serious symptoms can develop slowly and even without the presence of these cells. *Now it is generally recognized among experienced men that the whole clinical picture is essential to the diagnosis of lead poisoning.*

Stockvis has detected more than 40 years ago that in lead poisoning the excretion of porphyrine in the urine is augmented. Many authors showed the importance of this symptom, and it would be

useful to study it further and its precise value.

Once more there arose the danger of over emphasizing laboratory findings in the diagnosis of lead poisoning, as the progress of chemistry rendered possible the detection of minute amounts of lead in blood, urine and feces. It is to the merit of P. Schmidt, Weyrauch and their collaborators and of Fairhall, and of Kehoe, Thamann and their collaborators to have made the first profound researches of the quantities of lead in the blood and excreta in normal men and in healthy and sick lead workers. Their work gave information on the "normal" lead content and on the pathological content. It was not their fault if some practitioners thought that every increase of a lead content of the urine would be a sign of lead poisoning. It is also natural that a lead worker would have more lead in his urine than one not exposed. In his last publication, Fairhall has warned against the over emphasis of the lead content of the urine as a diagnostic sign, and has stressed the necessity of estimating the whole clinical picture.

As for the clinical symptoms, it must be said that the gravest forms, especially of *encephalopathy*, cannot be well studied with modern methods since they have become so much rarer. Certain pareses of muscles of the eyes and of the larynx observed prior to the time the Wassermann test was available can perhaps never be cleared up as to the true cause, but it is sure that lead poisoning produces in addition to the acute encephalopathy also a form which is more chronic and somewhat similar to paralysis progressiva.

In older literature we find "lead gout" mentioned. Tanquerel de Planches described the "arthralgia saturnina" and said that these pains mostly accompanying the lead colic disappear quickly as a rule, that they never make deformities as does chronic rheumatism. But textbooks made of "arthralgia saturnina" an "arthritis saturnina" or "gout saturnina" which does not exist.

PRACTICAL requirements cause us to differentiate between three stages which theoretically cannot be sharply separated from each other but which are of great value. We speak of lead *absorption* in every lead worker who has no signs of lead poisoning at all, or only the lead line in the gingival margins; we speak of *lead influences* if signs of lead poisoning are to be found (lead line, extensor weakness, punctate erythrocytes, either one of these alone or all together — but the single symptom or all of them together appear to such a slight degree that good health and efficiency are not diminished and are not threatened); by *lead poisoning* we refer to the phenomena resulting from lead which causes disturbances of the functions of the body or one of its organs, or produces a condition that continuing at lead work such a disturance is to be feared in a short time.

This distinction is needed for the supervision of lead workers through periodic physical examinations. Lead absorption is of very little importance. Lead influence calls for the attention of a physician and intensified examination. The last mentioned stage must cause temporary exclusion from lead exposure and treatment.

Another distinction which we have learned during the last decade is that between the symptoms of a *more acute and of a more chronic poisoning.*

Two complexes of symptoms appear as a rule as the consequences of absorption of lead in larger amounts and often through a shorter time—these being colic and encephalopathy. Paralysis is as a rule — though there are exceptions — the consequence of a longer absorption of lead after one or more attacks of colic, and also as the first illness after long absorption of very small amounts of lead. The most chronic manifestations are the changes of the vessels and of the kidneys which appear after lead absorption through decades without or with other preceding symptoms. However, further investigations are needed especially in regard to these changes.

Not only has our knowledge of the clinical picture of lead poisoning undergone some changes during the last decade, but also our conception of the whole nature of lead poisoning has undergone some revision as well. Many years ago the idea of lead poisoning was that lead is accumulated in the body and after this accumulation has reached a certain degree the illness begins. The picture is that of a filled vessel which another drop will overflow. Straub insisted in 1910 that it was not the lead stored in the body which rendered the individual ill, but the lead stream which is passing through the body and which on flowing through the organs produced the changes in them. These changes start the illness. The density and duration of the stream are important. A dense lead stream will rapidly produce colic, whereas paresis appears after prolonged flow of a diluted stream.

The best explanation of the further fate and effect of the lead in the body was given by Aub, Fairhall, Minot and Reznikoff who have shown that a large part of lead is excreted by the gastrointestinal tract and the kidneys, that the other part is stored first in the liver, and finally in the bones (which Heubel had already demonstrated in 1871). Stored in the skeleton the lead is harmless—the symptoms of plumbism being noted only when lead is generally distributed throughout the organism, as a result either of recent absorption from an external source, or of mobilization of the skeletal store. Aub and his collaborators have shown that a positive calcium balance favors the storage of lead whereas a negative balance tends to increase the rate of excretion. They, therefore, provided for us the means to a sound therapy, whereas all former therapy was only symptomatic.

As to prevention, our opinions have also changed. L. Tanquerel des Planches (1839), Thakhrah (1832) and Hirt (1825) stressed the importance of the inhaled lead but this was forgotten in the years of decline of industrial hygiene and pathology in 1880-1910, as medicine was dominated by bacteriology and especially so on the continent—physicians were excluded from factory inspection. Then the unique source of lead poisoning was believed to be entrance through the stomach and the lead

came into the stomach from the soiled hands by eating, smoking, chewing, and such practices. The fight against lead poisoning became very simple—cleanliness of the worker; if he fell ill, it was his own fault. The employer had only to provide washing facilities and proper eating rooms. It is to the merit of Thomas Legge on the basis of his large experience and of his collaborator Goadby through animal experimentation, to have proved recently the *prevalent* importance of lead dust in the air and its inhalation. On this knowledge the modern struggle against plumbism and its great success is based; we have thus seen a decreasing number of cases of poisoning as mentioned in the beginning of this article.

American Industrial Hygiene Association

IN THIS the first issue of special interest to the American Industrial Hygiene Association, we present to the members the interim constitution which was unanimously adopted at the preliminary organization meeting held in Cleveland June 3-7, 1939 in conjunction with the Annual Meeting of the American Association of Industrial Physicians and Surgeons.

Before considering the Constitution in detail, it may be well to consider briefly the recent events leading to its adoption. Discussions have been held for several years, debating the possibility of such an organization as is now in existence. These discussions reached a point in 1936-7 where definite action was contemplated. One result was the first Midwest Conference on Occupational Diseases held in 1937, in Detroit, in conjunction with the Annual Meeting of the American Association of Industrial Physicians and Surgeons. The second Midwest Conference was held in Chicago in 1938, and in 1939 a preliminary organization meeting was held during the sessions of the American Industrial Hygiene Conference in Cleveland. Much credit is to be given to DR. CAREY P. MCCORD and DR. CLARENCE D. SELBY, and to the American Association of Industrial Physicians and Surgeons, who were responsible for inaugurating the Midwest Conference and actively aiding in numerous ways the promotion of industrial hygiene organization efforts.

The two-day program of the 1939 Conference was arranged by WILLIAM P. YANT, WARREN A. COOK and GORDON C. HARROLD, acting as a committee for the American Association of Industrial Physicians and Surgeons. At the conclusion of this program, a meeting was held to consider the advisability of organizing an Industrial Hygiene Association. At that meeting a form of interim Constitution was presented; also, Officers and a Board of Directors, as provided for in the Constitution, were elected.

The Officers are:

WM. P. YANT .... *President*
WARREN A. COOK .... *President-Elect*
GORDON C. HARROLD .... *Secretary-Treasurer*

The Directors are:

J. J. BLOOMFIELD
D. E. CUMMINGS
PHILIP DRINKER
WM. G. FREDRICK
S. W. GURNEY
F. R. HOLDEN
F. A. PATTY
C. L. POOL
H. H. SCHRENK

A MEETING of the Board of Directors of the American Industrial Hygiene Association was held at the Pittsburgh Athletic Club 10 A.M., October 18, 1939. Nine of the officers and directors were present. These being a quorum, the meeting was officially called into session by the President.

It was unanimously agreed that 50 cents of the $3.00 annual dues be rebated to the local section at the option of such local group. This rebate was tentatively set up for the year 1940-41 as an aid in carrying on the activities of local groups in regard to sending out letters, calling local section meetings, and other incidental matters.

It was voted that acknowledgment of all material given at local or national meetings of the American Industrial Hygiene Association should appear as a footnote upon publication.

It was unanimously agreed that the dues should be $3.00 for the current year January 1, 1940 to January 1, 1941, for all members.

The Secretary-Treasurer was authorized to write to the Michigan Society of Industrial Hygienists to the effect that the Board of Directors have recommended to the Association the affiliation of established local industrial hygiene groups. Final action will be taken at the annual meeting.

The Board of Directors voted to meet in New York June 4-5, 1940, with the American Association of Industrial Physicians and Surgeons.

Without becoming the subject of a vote, an invitation was received from PROFESSOR PHILIP DRINKER to hold a future annual meeting at Harvard University, Boston.

A list of committees which would be useful in the conduct of the work of the Association was approved by the Board of Directors and will be incorporated in this report after the appointment of the committees by the President.

Some changes were made in the Constitution under Enabling Act, Article VII.

—GORDON C. HARROLD, *Secretary-Treasurer.*

Local Sections

A COMMITTEE has been appointed under Chairmanship of GORDON G. HARROLD for the formulation and development of local sections in various industrial centers of the country. Anyone interested in joining one of the local sections should contact the Committee Member in charge of that area, or GORDON C. HARROLD, Chairman. The above-named Committee is at the present time in process of being expanded.

Illinois:

WARREN A. COOK, Zurich General Accident and Liability Insurance Company, Ltd., Chicago.

Maryland:

D. E. METZGER, Director of Safety and Hygiene, Western Electric Company, Baltimore.

Michigan:

W. BRADLEY, Detroit Department of Health, Bureau of Occupational Diseases, and

A. C. FUNKE, Michigan Mutual Liability Company, Detroit.

New England:

C. R. WILLIAMS, Liberty Mutual Insurance Company. Boston, Mass., and

C. L. POOL, Bureau of Occupational Diseases, State Department of Health, Providence, R. I.

New York:

F. A. PATTY, Fidelity and Casualty Insurance Company,

J. WM. FEHNEL, Metropolitan Life Insurance Company, New York City.

Ohio (Southern Portion):

R. A. KEHOE, and W. MACHLE, Kettering Laboratories, University of Cincinnati, Cincinnati, Ohio.

Pennsylvania (Eastern Section):

LOUIS B. RAYCROFT, Electric Storage Battery Company. Philadelphia.

Pennsylvania (Western Section):

F. R. HOLDEN, Pittsburgh Plate Glass Company, Pittsburgh.

H. H. SCHRENCK, Pittsburgh Experimental Station, U. S. Bureau of Mines, Pittsburgh.

E. C. BARNES, Westinghouse Electric & Manufacturing Company, Pittsburgh.

West:

DONALD E. CUMMINGS, Director, Division of Industrial Hygiene, Colorado University School of Medicine, Denver, Colo.

Local Section News

PITTSBURGH LOCAL SECTION: The following officers have been elected:

Chairman—H. H. SCHRENK, PH.D., U. S. Bureau of Mines.

Secretary—E. C. BARNES, Westinghouse Electric & Manufacturing Company.

Executive Committee—E. W. GILLILAND, Mine Safety Appliances Company, H. F. SMYTH, JR PH.D., Carbon & Carbide Chemicals Corporation, and T. LYLE HAZLETT, M.D., Westinghouse Electric & Manufacturing Company.

A meeting was conducted for the Western Pennsylvania Branch of the American Society of Safety Engineers on December 13 on the subject "Respirators." The program consisted of "The Application of Respirators in Industry," by E. C. BARNES; "The Approval of Respirators by the Bureau of Mines," by H. H. SCHRENK, including a movie film; and "The Maintenance of Respirators," by E. W. GILLILAND, which also included a moving picture presentation.

THE next meeting of the Michigan Group will be held the middle of January, as will be that of the Western Pennsylvania Group.

The New York Group will hold their next meeting at 6:00 P.M. January 12, which will include a trip through the ventilating and carbon monoxide systems of the Holland Tunnel.

AT AN organization meeting of the Chicago Section, the following officers were elected:

Chairman—W. E. JEWELL, Supt. Sanitation and Industrial Hygiene, Inland Steel Company, Indiana Harbor, Indiana.

Vice-Chairman—CLARK D. BRIDGES, Safety Director, Casualty Mutual Insurance Company.

Secretary-Treasurer — HAROLD R. OHLHEISER, Division of Industrial Hygiene, Fidelity and Casualty Insurance Company.

Members of the Executive Committee—JAS. R. ALLAN, International Harvester Corporation; PAUL BRAND, Director of Safety and Compensation, Pullman-Standard Car Mfg. Company; A. J. R. CURTIS, Portland Cement Association; LESLIE M. RICE, Liberty Mutual Insurance Company; LESLIE C. STOKES, Engineer, State Dept. of Labor.

Constitution and By-Laws

—*of the American Industrial Hygiene Association*—

IT SHOULD be understood that this is an interim working constitution presented to characterize the nature of the organization and to crystallize the often expressed but never executed desires of industrial hygienists for an organization of their own. It should be noted that this constitution is to be voted on according to its provisions and the desires of the members at the annual meeting in June, 1940. The officers and members of the Board of Directors will be pleased to receive comments and constructive criticism from the membership concerning their desires in connection with this interim constitution which is now presented for consideration.

—GORDON C. HARROLD, *Secretary-Treasurer.*

Article I — Name

The name and title of this organization shall be the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION.

Article II — Object

This Association shall have as its object the advancement and application of industrial hygiene and sanitation through interchange and dissemination of technical knowledge on these subjects; the furthering of study and control of industrial health hazards through determination and elimination of excessive exposures; and the correlation of such activities as conducted by divers individuals and agencies throughout industry, educational and governmental groups; and the uniting of persons with these interests.

Article III — Membership

Section 1.—Members shall be persons who have an active interest in industrial hygiene.

Section 2.—A two-thirds vote of the Board of Directors shall be required to elect to membership.

Article IV — Officers and Directors

Section 1.—The officers of this Association shall be a President, a President-Elect and a Secretary-Treasurer. They shall be elected by the Association and shall serve until the close of the next Annual Meeting or until their successors are elected and installed. The President-Elect shall automatically become President without election on election of his successor. Presidents who have completed their term of office shall continue as members of the Board of Directors for two years following their term of office as President.

Section 2.—An Executive Secretary may be appointed by the Board of Directors. He need not be a member of the Association and shall hold his office at the pleasure of the Board of Directors.

Section 3.—The affairs of the Association shall be administered by a Board of Directors, consisting of the officers and nine directors and the two past presidents, next preceding the president in office. Three directors shall be elected each year and shall serve for a term of three years.

Section 4.—The planning of the work of the Association, arrangements for meetings and program and for other matters pertaining to the administration of its affairs, shall be vested in the Board of Directors, except as otherwise herein expressly provided. The Board shall have power to make rules governing procedure not provided for

by the Constitution and By-Laws. The President of the Association shall serve as Chairman of the Board. The Board shall make its own rules, and it and the President shall appoint such committees for carrying out the work as they shall deem necessary and desirable.

Section 5.—Executive Committee: The three officers of the Association and the two past presidents shall constitute the Executive Committee.

Article V — Local Groups and Affiliations

Section 1.—The Board of Directors shall have the power to take the necessary steps for fostering the formation of local groups and for admitting the members thereof to the Association.

Section 2.—Reciprocal affiliational relations as may be determined by the Board of Directors may be made with any local or national organization whose work and activities are closely allied to Industrial Hygiene. A group of this nature may become an affiliated society and its members admitted to Associated Membership in this Association, under conditions set up by the Board of Directors.

Article VI — Amendments

Amendments to this constitution may be proposed at any Annual Meeting by a three-fourths vote of the members present and voting. Proposed amendments must be circulated to the voting membership with a letter ballot. A three-fourths vote of all ballots returned shall be required for adoption.

Article VII — Enabling Act

During the preliminary organizational year, the Board of Directors shall have power to revise the constitution to provide an instrument which appears to satisfy the best interests of Industrial Hygiene and of the members of the American Industrial Hygiene Association. This article will become void automatically after the preliminary organizational year, not later than July 1, 1940.

BY-LAWS

Article I — Meetings

Section 1.—Ten per cent of the members eligible to vote shall constitute a quorum. The Annual Meetings of the Association shall be held at the time and place selected by the Board of Directors. In making arrangements for meetings, the Board of Directors shall, insofar as is feasible, join or affiliate with existing organizations that have a common interest.

Section 2.—Special meetings may be called by the President with the approval of five members of the Board of Directors.

Section 3.—Notice of all general meetings of the Association shall be sent to the members by the Secretary-Treasurer at least thirty days in advance of the date set for them.

Section 4.—Each member of the Board of Directors shall be notified in writing by the Secretary-Treasurer at least two weeks in advance as to the time, place and purpose of a meeting of the Board of Directors. A majority of the Board of Directors shall constitute a quorum.

Article II — Dues

Section 1.—The annual dues of members shall be $3.00 per year. Dues of members of component and affiliated societies shall be determined by the Board of Directors. Dues shall be payable in advance on the first day of January of each year. Dues shall not be required of Honorary Members.

Section 2.—Any member whose dues are unpaid is not in good standing, and he shall have no vote until his indebtedness is discharged. When the dues of any member shall not be paid during the fiscal year, his membership shall automatically terminate, except that in individual instances the action required by this Section of the By-Laws may be modified by two-thirds vote of the Board of Directors.

Section 3.—Any member dropped for non-payment of dues may be reinstated at any time previous to the convening of the Annual Meeting of the year following his delinquency by payment of dues in arrears and also the dues for the current year.

Article III — Election of Officers and Directors

Section 1.—Nominations for officers and directors shall be made by a nominating committee of three members to be appointed by the President at the first executive session of any Annual Meeting. Provided, this article shall not be construed so as to deprive any member of his right to make nominations from the floor. In making nominations for directors, the nominating committee shall give consideration to maintaining on the Board of Directors a balance of representation from agencies such as industry, governmental, educational and insurance, professional interests, and geographical areas.

Section 2.—Election of officers and directors shall take place at the last executive session of the Annual Meeting.

Section 3.—At each Annual Meeting there shall be elected to the Board of Directors three members to serve for a term of three years. Upon expiration of the term of office of the President, he shall become automatically a member of the Board of Directors to serve for two years.

Section 4.—In the event of there being competitive nominations for any office, election shall be by ballot, and a majority of all votes cast shall be required to elect. If after two ballots there shall be no election, all but the two candidates receiving the highest number of votes shall be dropped from the ballot and the voting confined to the two so designated.

Section 5.—The Board of Directors shall have power to fill vacancies among the officers and directors to serve until the next Annual Meeting of the Association or until their successors are elected and installed.

Article IV — Duties of Officers

Section 1.—The President shall preside at all meetings of the Association and of the Board of Directors and shall perform such other duties as may be directed by the Board of Directors. He shall also be an ex-officio member of all committees. In the absence of the President, the President-Elect shall act in his place.

Section 2.—The Secretary-Treasurer shall be the custodian of all money of the Association and shall pay all just bills against the Association subject to the approval of the Board of Directors; he shall submit his accounts for audit at the Annual Meeting of the Board of Directors and shall transmit to his successor in office all funds and property of the Association remaining in his possession. He shall submit an annual report to the Association in such form as may be determined by the Board of Directors. He shall be bonded in such an amount as shall be determined by the Board of Directors from year to year and in a company approved by the Board of Directors. Expense of bond shall be borne by the Association.

Section 3.—The Secretary-Treasurer shall keep an accurate record of all the transactions of all meetings of the Association and of the Board of Directors; shall carry on the correspondence of the Association; shall keep an accurate list of the members and their status; shall receive all money belonging to the Association, giving receipt therefor.

Section 4.—The Executive Committee shall transact the duties of the Board of Directors in emergencies or in any special assignment from the Board of Directors. It shall pass upon the application of local groups and affiliates and complete arrangements for their admission into the Association or for reciprocal relations. Its actions shall be subject to the approval of the Board of Directors.

Section 5.—The Board of Directors shall hold regular meetings at least once a year, at which time they shall consider applicants for membership.

Article V — Committees

Section 1.—The President shall appoint a program committee, consisting of two Members, the President-Elect and the Secretary-Treasurer. The duty of the Program Committee shall be to provide the program for each meeting of the Association.

Section 2.—The President shall appoint other committees as the Association or Board of Directors may recommend or at his own discretion for any special purpose pertaining to the Association or its activities.

Section 3.—The President shall appoint a membership committee of three Members, whose duty it shall be to

investigate and pass upon all applicants for membership before they are referred to the Board of Directors for their consideration.

Article VI

Section 1.—All resolutions shall be referred to appropriate committees for recommendation before submitting them to the Association.

Section 2.—Membership of any member may be terminated for such cause as the Board of Directors may deem sufficient; provided that a copy of the charge made against him shall be furnished to him in writing at least thirty days before the meeting at which such action is taken. A three-fourths vote of all members of the Board of Directors shall be required to terminate membership.

Article VII — Amendments

Section 1.—Amendments to By-Laws may be proposed at any Annual Meeting by a majority vote of the members present and voting. Proposed amendments shall be circulated to the voting membership with a letter ballot. A majority of letter ballots returned shall be required for adoption.

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